


FORM PTO-1390 (REV 5-93)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 225/49845	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/807125	
INTERNATIONAL APPLICATION NO. PCT/EP99/06591		INTERNATIONAL FILING DATE 7 September 1999 (07.09.99)		PRIORITY DATE CLAIMED 8 October 1998 (08.10.98)	
TITLE OF INVENTION: MEASUREMENT OF SMALL, PERIODIC UNDULATIONS IN SURFACES					
APPLICANT(S) FOR DO/EO/US: Joerge BAUMGART; Norbert RAU and Horst TRUCKENBRODT					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
<p>1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.</p> <p>3. <input type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).</p> <p>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</p> <p>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)).</p> <p>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</p> <p>6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</p> <p>7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). UNEXECUTED (2 pages)</p> <p>10. <input checked="" type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</p> <p>Item 11. to 16. below concern other document(s) or information included:</p> <p>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment.</p> <p><input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</p> <p>14. <input checked="" type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input checked="" type="checkbox"/> Other items or information: Form PCT/IB/308; First page of PCT International Application; Amended Sheets 1, 2, 3, 4a, 4b, 4c; Five Sheets of Drawings showing Figures 1-8</p>					

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
09/807125		PCT/EP99/06591		225/49845	
17. [X] The following fees are submitted:				CALCULATIONS	
Basic National Fee (37 CFR 1.492(a)(1)-(5)):				PTO USE ONLY	
Search Report has been prepared by the EPO or JPO \$860.00				\$ 860.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) \$690.00					
No international preliminary examination fee paid to USPTO (37 CFR 1.482)					
but international search fee paid to USPTO (37 CFR 1.445(a)(2)) \$710.00					
Neither international preliminary examination fee (37 CFR 1.482) nor					
international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$ 1000.00					
International preliminary examination fee paid to USPTO (37 CFR 1.482)					
and all claims satisfied provisions of PCT Article 33(2)-(4) \$100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT = \$					
Surcharge of \$130.00 for furnishing the oath or declaration later than [] 20 [] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$ 130.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	13-20=	0	X \$18.00	\$	
Independent Claims	2-3=	0	X \$80.00	\$	
Multiple dependent claims(s) (if applicable)			+ \$270.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$ 130.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$	
SUBTOTAL =				\$ 990.00	
Processing fee of \$130.00 for furnishing the English translation later than [] 20 [] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$ 990.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). \$40.00 per property +				\$	
TOTAL FEE ENCLOSED =				\$ 990.00	
				Amount to be: \$	
				refunded	
				charged \$	
<p>a. [X] A check in the amount of \$ 990.00 to cover the above fees is enclosed.</p> <p>b. [] Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. [X] The Commissioner is hereby authorized to charge any additional fees, which may be required, or credit any overpayment to Deposit Account No. <u>05-1323</u>. (Attorney Docket No. <u>225/49845</u>.) A duplicate copy of this sheet is enclosed.</p>					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO:					
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JCO3 Rec'd PCT/PTO 09 APR 2001

Attorney Docket: 225/49845
PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: JORG BAUMGART ET AL.
Serial No.: NOT YET ASSIGNED PCT No.: PCT/EP99/06591
Filed: APRIL 9, 2001
Title: MEASUREMENT OF SMALL, PERIODIC UNDULATIONS IN
SURFACES

PRELIMINARY AMENDMENT

Box PCT
Commissioner for Patents
Washington, D.C. 20231

April 9, 2001

Sir:

Please enter the following amendments to the specification and claims, as amended by way of Annexes to the International Preliminary Examination Report for PCT/EP99/06591, prior to the examination of the application during the U.S. National Phase.

IN THE SPECIFICATION:

Submitted herewith is a substitute specification and marked-up copy thereof which includes the changes made by way of the Annexes to the International Preliminary Examination Report.

IN THE CLAIMS:

Please cancel all of the claims presently in the application and substitute new Claims 14-26, as follows:

14. (new) A method for detecting small periodic wave patterns in surfaces, comprising:

illuminating the surface using a primary beam of monochromatic coherent light which is directed onto the workpiece surface at a large angle of incidence with respect to the surface normal to the surface of the workpiece and approximately at right angles to expected periodic wave patterns;

detecting a diffraction image of the periodic wave patterns produced in the secondary light returned by the surface; and

evaluating an intensity distribution of the diffraction image; wherein,

for separate determination of the wave pattern of a ground surface, in which the wave pattern has finer, steeply indented stochastic ground structures superimposed on it, the

ground structures are shadowed by approximately grazing incidence of the primary light beam onto the workpiece surface at a constant angle of incidence within an angular range of approximately $83 \pm 2^\circ$, whereby a diffraction image solely representing the wave patterns is produced because of an isolated illumination of the wave patterns thereby achieved with primary light on their sides facing towards and away from the light and on respective wave crests.

15. (new) The method according to Claim 14, further comprising:

collecting the secondary light beam on a matt panel;

and

visually evaluating its intensity distribution with respect to the occurrence of intensity maxima.

16. (new) The method according to Claim 14, further comprising:

measuring an intensity distribution of the secondary light as a function of position over an image area of the diffraction image; and

evaluating the measurements with respect to occurrence of intensity maxima.

17. (new) The method according to Claim 16, further comprising:

subjecting the intensity distribution of the secondary light to an autocorrelation; and

evaluating the autocorrelation function obtained therefrom.

18. (new) The method according to Claim 14, wherein:

spacing of neighboring intensity maxima is determined;
and

period of the wave pattern is deduced therefrom.

19. (new) The method according to Claim 18, wherein:

intensity values of neighboring intensity maxima are determined; and

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depth of wave troughs between wave crests is deduced therefrom and from the period of the wave pattern.

20. (new) A device for detecting small periodic wave patterns in the surface of a workpiece, said device comprising a meter which is adapted to be placed in a defined way on the workpiece surface to be analysed, with a primary-light source which directs a primary light beam of monochromatic, coherent light beam onto the workpiece surface in a predetermined direction, and a secondary-light display which collects a scattered-light cone returned by the workpiece surface in the meter, wherein:

at least in a region where the primary-light beam emerges from the meter, it is directed in such a way that, when the meter is placed on the workpiece, it strikes the workpiece surface to be analyzed at an angle in the range of approximately $83 \pm 2^\circ$;

the meter is designed so that, after placing on the workpiece surface, it can be aligned with respect to the primary beam at least approximately at right angles to any expected periodic wave patterns of the workpiece surface;

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the secondary-light display collects the scattered-light cone without imaging optics, as a diffraction image of a wave pattern; and

an intensity distribution in the diffraction image is evaluated.

21. (new) The device according to Claim 20, wherein:

in an area to be applied to the workpiece surface, the device has an exit window;

deflecting elements for the primary beam and the secondary beam are arranged in a lateral periphery of the exit window; and

the deflecting elements deflect the light beams such that a beam component of the primary beam located in front of the primary-beam deviating element and a beam component of the secondary beam located behind the secondary-beam deviating element are aligned approximately at right angles to the workpiece surface.

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22. (new) The device according to Claim 21, wherein the optical deflecting elements are arranged in such a way that the beam component of the primary beam located in front of the primary-beam deviating element and the beam component of the secondary beam located behind the secondary-beam deviating element cross each other.

23. (new) The device according to Claim 20, wherein the secondary-light display comprises a matt panel which makes the intensity distribution of the diffraction image visually perceptible.

24. (new) The device according to Claim 20, wherein the secondary-light display comprises one of a linear and a two-dimensional matrix of a plurality of photoreceptive sensors which measure the intensity distribution of the diffraction image.

25. (new) The device according to Claim 20, wherein

both a matt panel, which makes the intensity distribution of the diffraction image visually perceptible, and one of a linear and a two-dimensional matrix of a plurality of photoreceptive sensors which measures an intensity distribution

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of the diffraction image, are arranged in the secondary-light display; and

the secondary-beam path is accessible via one of a beam splitter and a tilting mirror.

26. (new) The device according to Claim 25, further comprising a digitally operating camera which is fitted to the meter and positioned to record the intensity distribution of the diffraction image of the secondary-beam path.

IN THE ABSTRACT:

Please substitute the new Abstract of the Disclosure submitted herewith on a separate page for the original Abstract presently in the application.

(Applicant's Remarks are set forth hereinbelow, starting on the following page.)

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REMARKS

Entry of the amendments to the specification and claims, as amended by way of Annexes to the International Preliminary Examination Report for PCT/EP99/06591, before examination of the application in the U.S. National Phase is respectfully requested.

If there are any questions regarding this Preliminary Amendment or this application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #225/49845).

Respectfully submitted,


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ABSTRACT OF THE DISCLOSURE

In a method and apparatus for detecting small periodic wave patterns in technical surfaces using the scattered-light method, the surface is illuminated using a primary light beam and the secondary light returned by the surface is analyzed. For this purpose, monochromatic, coherent primary light is directed onto the workpiece surface approximately at right angles to the expected periodic wave patterns - grazing the workpiece surface. A diffraction image of the waved surface structure, whose intensity distribution can be evaluated visually or by use of measuring instruments, is produced in the secondary-light beam. The occurrence of two intensity maxima immediately indicates the presence of a periodic wave pattern. The period of the wave pattern can be deduced through inverse proportionality from the spacing of neighboring intensity maxima, and the depth of the wave troughs between the wave crests can be deduced from the intensity of neighboring intensity maxima and from the period. The intensity distribution in the diffraction image in the secondary-beam path is subjected to an autocorrelation, and both the period and the depth of the wave pattern can be calculated from the autocorrelation function. When the meter is placed properly on the workpiece, the primary-light beam strikes the workpiece surface at an angle of incidence of preferably about 83 ± 2 degrees, the beam path being folded in a space-saving way.

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Measuring small periodic wave patterns in surfaces

The invention is based on a method and an
5 arrangement for detecting and measuring periodic small
wave patterns in technical surfaces, respectively
according to the precharacterising clause of Claim 1
(method) and according to the precharacterising clause of
Claim 7 (arrangement), as disclosed for example by US
10 Patent 3 850 526.

Since, on finely processed workpiece surfaces,
the Applicant was able to observe unintended wave
patterns of the type of interest here with a period up to
about 1.5 mm, and the possibility that there may be even
15 longer periods for wave patterns of the type in question
here cannot be ruled out, the term "small wave patterns"
will be used here to denote those having a spacing
between the wave-structure peaks smaller than two
millimetres, although in most cases the periods are
20 significantly less than one millimetre.

For a reliable sealing function at points where
shafts pass through housing walls, besides the sealing
ring provided with an annular radial sealing lip it is
also necessary to take into account the properties of the
25 opposed running surface on the shaft. To produce a smooth
surface at such shaft journals, they may be
circumferentially ground, finished on a lathe, burnished,
rolled or externally abraded. Besides specific roughness
values, the manufacturer of the shaft journal also
30 prescribes the degree to which the surface is free from
torsion. Torsion-free, for example in the case of ground
surfaces, means that the ground structure lies precisely

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in the circumferential direction and there are no superimposed regular wave components. However, in modern mass production it is not only difficult to create technical surfaces reproducibly without torsion, but
5 problems are also encountered in reliably detecting such freedom from torsion and, where necessary, quantifying any torsional structure.

DE 197 40 141 A1, in the name of the Applicant, describes a mechanically operating test-score method for
10 detecting and quantifying torsional structures or wave patterns that are of interest here, which leads to reliable and quantitatively comprehensive information concerning virtually all relevant parameters of the torsional structure. The known test-score method gives
15 usable results, in particular even if the wave pattern is not very pronounced and/or has a strong stochastic roughness component superimposed on it, when the stochastic roughness component has been substantially removed by means of an autocorrelation of the surface
20 data. However, the known method of generating the surface data is very time-consuming and must be carried out very carefully. This method cannot therefore be used to monitor directly the manufacturing of technical surfaces. Instead, this method can be used as a reference method to
25 control other torsional determination methods.

A prior application of the Applicant according to DE 198 09 790 A1, which was published after the priority date of the present patent, describes a contactlessly, optically operating method in which the raw data of the
30 surface to be analysed are obtained from direct, magnified imaging of a small segment of the surface. The method operates with arbitrary light as the primary-light

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type. The surface illuminated by it is sharply focused on a matt panel or on a high-resolution photodiode array by the use of imaging optics. In this method, coarse and strongly inclined torsional structures can be detected
5 directly from the visual appearance of the image, without further processing of the image data. Such strongly pronounced torsional structures, however, can be detected by a trained eye anyway, i.e. merely with suitable illumination and with the aid of a lens. Such coarse
10 cases generally occur rarely in practice and do not cause problems with regard to their detection. In the case of less pronounced and/or less inclined torsional structures, however, according to the said method it is necessary to generate image-data records of a plurality
15 of neighbouring surface parts and combine them as a function of position to form a uniform image-data record, each individual image-data record being respectively subjected beforehand to a Radon transformation.

Although the said torsional determination method
20 according to DE 198 09 790 A1, which was published after the priority date of the present patent, operates faster than the test-score method, it nevertheless also requires some degree of care since, on the one hand, the reference position of the workpiece with respect to the measuring
25 instrument must be known accurately and, on the other hand, the measuring device and the workpiece must be held exactly stationary relative to each other during the measurement. In the known relative position of the workpiece axis and the measuring instrument, it is
30 necessary to take a plurality of recordings in close succession, which is also time-consuming and requires care. Furthermore, the evaluation also requires some

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degree of care and supervision since the individual images must be matched to one another with a view to uniform average grey-scale distribution. The known method does provide information about the spacing of the wave patterns and their inclination with respect to a reference direction. However, information about the depth of the wave patterns and their cross section cannot be obtained directly using this method and can only be obtained with restrictions. The known method can be used in the laboratory to detect the presence or absence of surface torsion in a limited number of prepared workpieces, but the method is less suitable for use in manufacture.

US Patent 3 850 526, which was mentioned in the introduction, discloses a method and a device for the optical detection of periodic wave patterns in finely processed workpiece surfaces, in which the latter are illuminated with a beam of monochromatic, coherent light - primary light - and a diffraction image of the periodic wave patterns is produced in the secondary light returned by the surface. In this case, the primary light is directed onto the workpiece surface at a large angle of incidence with respect to the normal to the surface and approximately at right angles to the expected periodic wave patterns, and the intensity distribution of the diffraction image is evaluated. Of the beams involved, that is to say the incident primary-light beam and the emerging secondary beam, one is in that case kept at a fixed angle of at most 80° with respect to the normal to the surface, whereas the beam or evaluation channel of the other respective beam can be moved through a relatively large angle range around the position of the

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reflected beam. By means of a tilting beam arrangement,
the strongest diffraction orders are fully detected and
measured in terms of its intensity profile. By comparing
the intensity distribution of the diffracting light
5 measured using a workpiece with intensity distributions
obtained beforehand using various roughness standards,
the surface roughness of the workpiece to be analysed can
be found. The known type of surface inspection is not,
however, applicable to ground surfaces in which two
10 different fine shape structures are superimposed on each
other, but only one of which is of interest. The
diffraction image of the periodic wave patterns would
have specular noise of the stochastic ground structures
superimposed on it to the extent that it could not be
15 identified and therefore could not provide useful
information.

US Patent 5 189 490 discloses a normal roughness
measurement using the scattered-light method, in which a
primary-light beam is reflected by the surface to be
20 analysed and the reflected secondary beam is in this case
scattered in a way characteristic of the roughness
structure of the surface. Using this scattered-light
method, which is widespread in principle and in different
configurations and/or applications, neither diffraction
25 by a periodic diffraction structure nor alignment of the
primary light at right angles to the orientation of
parallel processing tracks take place. The method
disclosed by the cited document indirectly provides
qualitative and quantitative useful information about the
30 surface to be analysed only after comparison of the
actual pattern of the scattered-light cone, obtained from

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the specimen, with a large number of stored reference patterns produced beforehand using known patterns.

US Patent 3 782 827 discloses a very similar comparison method, which operates according to the
5 scattered-light method, for determining the roughness structure of technical surfaces. This measurement method only supplies a certain actual pattern of a scattered-light distribution of the respective specimen. By
10 similarity comparison with a large number of stored reference patterns, it is possible indirectly only to find useful information as to whether or not the analysed specimen has a similar surface topography to a known sample.

It is an object of the invention for the basic
15 method of the generic type, and a corresponding arrangement, to be improved in terms of manufacturing compatibility to the extent that a measurement can be carried out quickly, conveniently and with reproducible information being obtained. In particular, the intention
20 is for exact relative alignment of the workpiece and the device to be no longer necessary for the measurement result; nevertheless, the intention is also to ensure sufficient stability of the measurement image even in the event of relatively unstable handling both of the
25 workpiece and of the device. In this case, the intention is for a single measurement to give not only reliable quantitative information, as to whether a periodic surface wave pattern is "present" or "not present", but qualitative information about the period and the depth of
30 the wave pattern should also be possible where appropriate - with corresponding image-data evaluation.

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On the basis of the method of the generic type,
this object is achieved according to the invention by the
characterising features of Claim 1 and, with respect to
the corresponding arrangement, by the characterising
5 features of Claim 7.

According to the invention, by means of
monochromatic, coherent light which strikes the wave
crests on the surface at right angles to their length at
a large angle of incidence - approximately grazing
10 incidence - and by exploiting the diffraction by the
waved surface structure as a diffraction grating, a
diffraction image is produced and the intensity
distribution therein is evaluated. Owing to the large
angle of incidence of the light, the effect of the
15 scattered light from the stochastic ground structure in
the diffraction image is substantially eliminated. The
diffraction image remains stable and stationary even if
the degree to which the measuring instrument is held

20 (The description continues as at the top of page
5 in the original documents)

5 diffraction image is produced and the intensity distribution therein is evaluated. Owing to the large angle of incidence of the light, the effect of the scattered light from the stochastic ground structure in the diffraction image is substantially eliminated. The diffraction image remains stable and stationary even if the degree to which the measuring instrument is held stationary relative to the workpiece varies. Furthermore, the quality of the diffraction image does not depend, within realistic limits, on the relative alignment of the workpiece and the measuring instrument. The presence of a torsional structure can be detected immediately from the occurrence of a local intensity maximum in the scattered-light cone. The spacings of the wave crests can be deduced from the spacing of a plurality of maxima - where different diffraction orders are involved. In this case, the spacings of the intensity maxima vary approximately in inverse proportion to the wave-crest spacings, i.e. a very close succession of wave crests causes widely spaced brightness maxima in the intensity distribution of the scattered-light cone, whereas the intensity maxima are closer together if the spacings of the wave crests are larger. It is even possible to deduce the depth of the wave troughs by evaluating the intensities of the different diffraction orders and the period. However, it is difficult to obtain information about the angular position of the wave patterns in relation to the exact circumferential direction in the present invention.

30 Before explaining the invention further, a few comments will be made regarding the terminology. On the one hand, there are repeated references to "primary light" and "secondary light" and, on the other hand, there are references to a "diffraction image" in the secondary beam. The term "primary light" used here means
35 light which is sent onto the workpiece surface to be

analysed, that is to say incident light. The "secondary light" is not, for instance, light due to a fluorescence phenomenon, but the light which is returned, scattered, diffracted or reflected by the workpiece surface.

5 Furthermore, despite the fact that the term "diffraction image" is used, the idea should not be inferred that a method which forms an image or a device which forms an image is involved in the present case. The primary light is diffracted by the waved surface structure and an
10 intensity distribution corresponding to the diffraction is created in the secondary beam. "Diffraction image" means the specific nature of the relevant intensity distribution of this diffraction. A pictorial representation of the "diffraction image" for evaluating
15 this intensity distribution, e.g. by using lenses or the like which form images, is not only unnecessary but would be incorrect. The direct collection of the "diffraction image" on a matt panel is sufficient for the visual intensity evaluation.

20 Expedient refinements of the invention can be found in the dependent claims; the invention is furthermore explained in more detail below with the aid of exemplary embodiments represented in the drawings, in which:

25 Fig. 1 shows a perspective representation of a handset for the inspection according to the invention of workpiece surfaces with respect to periodic wave patterns by visual assessment of the secondary light,

Fig. 2 shows a cross section through the lower
30 part of the handset according to Figure 1,

Fig. 3 shows a handset according to Figure 1 which is held in a stand above a workpiece mount and has a digital camera connected via an adapter,

Fig. 4 shows a greatly enlarged and enhanced
35 cross section through a small segment of a workpiece

surface, in which a small segment is furthermore detailed with even greater enlargement,

Fig. 5 likewise shows a greatly enlarged and greatly enhanced cross section through a segment of a different workpiece surface having two superimposed periodic wave patterns of different wavelength,

Fig. 6 shows the diffraction-image display which can be obtained when observing the workpiece surface according to Figure 5 using the handset according to Figure 1,

Fig. 7 shows, in the upper part (a) of the image, a two-dimensional brightness distribution of a diffraction image (represented in negative) and, in the lower part (b) of the image, a diagram corresponding thereto which represents the profile of the intensity along the line b-b in part (a) of the image, and

Fig. 8 shows a diagram which describes the relationship between an auxiliary variable k , determined from the intensity values i_1 and i_2 , the period L of the wave pattern and the wave depth T , and is used to determine the wave depth T .

Figures 1 and 2 show a handset 1 which is intended to detect small, periodic wave patterns (Figure 4 or 5) in the surface 12 of a workpiece 11 and operates according to the scattered-light method. It is placed in a deliberate way on the workpiece surface 12 to be analysed. A light pencil - light wave - emitted by a primary-light source is directed onto the workpiece surface in a specific direction and the scattered-light cone returned by the workpiece surface is collected in a secondary-light display of the meter.

In order to make the handset compatible with manufacture, and to be able to detect small, periodic wave patterns quickly, conveniently and with reproducible information being obtained using it, according to the invention it is designed in the following way:

The handset 1, which is configured in an ergonomically expedient way and is provided with a lightweight plastic housing, is handy and, because of the mode of operation according to the invention, it can also be guided manually and nevertheless delivers measurement images which are positionally stable. A laser diode 6 with integrated collimation optics is built into the handset as a primary-light source, and emits a monochromatic, coherent primary-light beam 7. In principle, a He/Ne laser could also be used as the primary-light source, although this is not as compact as a laser diode and is not recommendable here for handsets of the proposed type on grounds of size. A power corresponding to protection class I for low-power laser devices is sufficient for the present purposes. A battery compartment which can be closed by a flat-head screw 3 is integrated in the handset. The Mignon cell which it holds delivers the energy for the primary light, which can be switched on and off as required using a switch 4 arranged next to a knurled ribbed surface 5 so that it can be gripped easily.

In the region where the primary-light beam 7 emerges from the handset 1, an application surface 2 for placing the device on the workpiece surface 12 to be analysed is provided on the device housing. Since the intention is to carry out analysis on relatively curved as well as flat surfaces, in the exemplary embodiment which is represented the application surface is of flat configuration and is reinforced by a small steel plate which encloses the exit window. In the region of this exit window, the deviating mirror 14 deflects the primary beam 7 so that it strikes the workpiece surface 12 to be analysed at approximately grazing incidence (incidence direction 16) when the meter 1 is placed properly on the workpiece 11. To be precise, the primary-light beam 7 strikes the workpiece surface 12 to be analysed at a

specific, larger angle of incidence which - measured from the normal 13 to the surface - may lie in the range of about 75-88 degrees, preferably about 83 ± 2 degrees. Because of the flat configuration of the handset application surface 2, after placing on the workpiece surface it can be aligned with respect to the primary beam 7 at least approximately at right angles to any expected periodic wave patterns 26 of the workpiece surface 12, by slight tilting of the device about the height axis. In the secondary-light region - apart from a deviating mirror - no installed optical parts, that is to say no imaging or focusing optics or the like, for example, are provided in the handset. The secondary-light display directly collects the diffraction image caused by the primary light on the waved structure of the workpiece surface. The intensity distribution of the diffraction image is evaluated in order to detect any periodic wave patterns in the workpiece surface.

Since the wave patterns to be picked up on usually cylindrical workpiece surfaces are oriented in the circumferential direction, the axis of the incident primary beam must lie at least approximately in a plane which includes the cylinder axis. In order to make it possible to place the handset properly in the axial direction (Figure 2) on relatively short and set-back component surfaces, the handset must be configured in a space-saving way in the region of the exit window. The primary beam 7 and the secondary beam 8 are therefore space-savingsly bent in the handset in such a way that the front primary-beam component and the rear secondary-beam component are essentially aligned at right angles to the workpiece surface 12. To that end, a small deviating mirror 14 for the primary beam and another small deviating mirror 15 for the secondary beam are respectively arranged laterally at the boundary of the exit window, i.e. at a small difference from the point

where the primary beam 7 strikes the workpiece surface. In the exemplary embodiment which is represented, in order to make it possible to give the lower part of the housing, the beam shaft, a particularly short configuration as viewed in the axial direction of the component 11, the deviating mirrors 14, 15 are arranged in such a way that the beam component of the primary beam 7 located in front of the primary-beam deviating member 14, on the one hand, and the beam component of the secondary beam 8 located behind the secondary-beam deviating member 15, on the other hand, cross each other at a relatively small angle. This beam arrangement makes it possible not only to achieve an especially space-saving construction design in the front part of the handset, but it is also thereby possible to minimise the number of beam deviations required, which besides minimal loss of luminous efficiency, not only provides cost and weight advantages but also maintenance and adjustment advantages.

Instead of the deviating mirrors, it is also possible to use a deviating prism. Optionally, the deviating prism could advantageously be combined to form a stable module with the said reinforcing plate for limiting the exit window.

In the handset 1, the secondary-light display is designed as a matt panel 10 which makes the intensity distribution of the diffraction image immediately visible, so that it can be visually assessed and even preliminarily evaluated. The intensity distribution of the diffraction image, which can be seen on the matt panel, stays steady on the matt panel even if there is some degree of manual movement for the workpiece and/or for the handset. In order to shut out interfering extraneous light, the matt panel is arranged set-back at the bottom of an observation shaft 9. The latter may also

be used to fit a photodetector or a digital camera to the handset.

For quantitative evaluation of the diffraction image, the intensity therein must be measured. To that end, a photodetector linear array or a photodetector matrix should be provided. Such a photodetector is not provided in the exemplary embodiment represented in Figures 1 and 2. It is, however, conceivable to provide such a photodetector instead of the matt panel 10. Suitable examples for this include CCD linear arrays or CCD matrices, spectrometer linear arrays or matrices, other photodiode linear arrays or matrices or the like. In this case, however, it would be expedient if a matt panel, on which the intensity distribution of the diffraction image can be directly collected and perceived, and a photodetector of the said type, which can be used to measure the intensity distribution of the diffraction image as a function of position, are both arranged in the secondary-light display. This being the case, the secondary-beam path may be delivered to the matt panel, on the one hand, or the photodetector, on the other hand, either simultaneously - by means of a beam splitter - or successively - by means of a tilting mirror. The intensities measured by the photodetector may be evaluated using a computer which is provided. Another possible way of evaluating and displaying the measurements is to couple the photodetector with a digital signal processor and an LCD display. The advantage of the latter variant involves compact design of the measuring instrument, including the associated data-processing system, without an additional computer unit.

Figure 3 represents yet another possible way of controlled evaluation of the secondary light, which also uses the handset. In this case, the handset 1 is held stationery by means of a holding device 21 and a stand 20

on a table 18, above an insertable prism 19 for a workpiece 11. An adapter 22, by which a digitally operating camera 23 is fitted to the handset, is placed stably in the observation shaft 9 of the handset 1 (see 5 Figure 1). The digital camera, which carries the adapter 22 instead of its objective lens, may be lifted off or fitted on the handset as required. The matt panel needs to be removed when the digital camera is fitted on. The secondary light can then be observed in the viewfinder of 10 the digital camera. With the recording technique of the digital camera, the intensity distribution of the diffraction image of the secondary-beam path 8 can be recorded and stored, as a data-processable record of the image data, on a special data medium which is integrated 15 in the camera but can be removed.

The recorded image data can be forwarded in various ways from the manufacturing facility to an evaluation laboratory, from where the results, that is to say the parameter values of the wave-pattern structure of 20 the surface can be sent back to the manufacturing facility. The image data can be sent on data medium, that is to say on special camera-data medium or - after downloading to a conventional floppy disk - on such a floppy disk as the data medium. The image data may, 25 however, also be sent down a line to the evaluation laboratory by means of data transmission.

The procedure involved in the detection and, where appropriate, quantitative determination of the surface-wave patterns using the described device will be 30 discussed in more detail below with reference to the surface structures according to Figures 4 and 5 which are represented in a greatly magnified and enhanced form. The macroscopic configuration of the e.g. circumferentially ground surface of the workpiece 11 (Figure 4) or 35 11' (Figure 5) is scarcely recognisable as a continuous surface in these detailed representations.

In this context, two topographical terms which are used here, namely "ground structure" in the sense of a superimposed stochastic fine structure, on the one hand, and periodic "torsional structure" or "wave pattern", on the other hand, will firstly be explained. Both terms relate to micro-deviations from the ideal macroscopic form of the surface, but the two microstructures differ with respect to the criteria of interest here, on the one hand by the extent or depth with which they occur on the workpiece. On the other hand, the two microstructures differ in a formal and statistical respect. The fine ground structures 24 (see Figure 4), which are generally aligned precisely in the circumferential direction, have comparatively steep side edges but their cross section substantially occurs stochastically in other regards. Conversely, the torsional structures or wave patterns 26 observed are substantially flatter on the edges and have a relatively pronounced periodic shape component. A ground structure 24, which is formed by a plurality of small, stochastic indentations and has steeper edges and substantially smaller depth dimensions than the wave pattern, is typically superimposed on a periodic wave pattern or torsional structure 26.

In the profile according to Figure 4, waves 26 are arranged regularly, that is to say periodically next to one another. Because of the greatly enhanced representation of the roughness profile, the illumination direction 16 represented as an arrow is no longer angularly correct, i.e. the flatly incident primary radiation 8 still actually reaches the bottom of the troughs and the side edges of the wave patterns away from the light. With this approximately grazing illumination, however, the steeply cut indentations of the ground or fine structure 24 are substantially shadowed (shadow zones 25), so that they can only affect the returned

light to a very small, virtually negligible extent. Conversely, the substantially flatter torsional structure 26 is substantially illuminated. Therefore, diffraction of the monochromatic and coherent primary light takes
5 place substantially more strongly on the waved torsional structure than any superimposed diffraction on the ground structure 24. The zeroth diffraction order lies in the direction 17 of the secondary beam 8, which corresponds to that of the deviated direction reflected directly by
10 the ideal macro-surface. If the surface is waved and diffraction occurs, then a further diffraction order, namely the first, can generally also be perceived at a certain spacing next to the zeroth diffraction order in the diffraction image.

15 The wavefronts which emerge from the various wave crests 27 and have stacked depths, interfere with one another and cause a diffraction image in the secondary light, only the zeroth and first diffraction orders of which can be seen as intensity maxima. If no periodic
20 wave patterns are present on the surface, then no diffraction image is formed in the secondary light. In this case, two spaced intensity maxima cannot be perceived. A "reflective diffraction grating", that is to say a series of periodic waves in the surface to be
25 analysed, can therefore reliably be deduced from the occurrence of two different intensity maxima.

Other surface structures cause other intensity distributions in the secondary light. For example, an ideally reflective surface replicates the intensity
30 distribution of the primary beam in the secondary beam as well. In such a case, only a single bright spot can be perceived in the secondary light. If there is a surface with entirely stochastic roughness and no periodic wave patterns, a uniform intensity distribution with a
35 relatively pronounced specular structure will be observed.

At this point, for the sake of completeness, it should be mentioned that the bright spots appear as ovals which are relatively distorted in the axial direction according to the strength of the curvature of the cylindrical surface 12; in the case of smaller cylinder diameters, the major axis of the oval may be larger than the corresponding internal width of the matt panel, so that the bright spot appears as a bright line.

With reference to the example of the two Figures 5 and 6, the way in which the method according to the invention can also be used to deduce the period of the regular wave pattern will now be explained. The surface texture of the workpiece 11', which is represented on an enlarged scale in Figure 5, has two superimposed periodic wave patterns with very different period, namely small waves 26_k with a small period L_k and large waves 26_g with a large period L_g . If this surface is "observed" using the handset 1, the image shown in Figure 6 appears on its matt panel 10. Two intensity maxima can be seen, which are resolved in strips and have a relatively large mutual spacing a_k , which is attributable to the small waves 26_k . The individual strips of the two intensity maxima have a relatively small spacing a_g from one another, which is associated with the wave pattern of the large waves 26_g .

There is an approximate inverse-proportionality relationship between the spacing a of the intensity maxima within the diffraction image of the secondary light and the period L of the wave pattern: the smaller the spacing a of the bright spots is, the larger is the period L of the wave pattern, and vice versa. Using the equation $a \approx f/L$, the period L can be determined to good approximation from the spacing a of the intensity maxima. The factor f contained therein is an instrument constant, which needs to be empirically determined beforehand using known surface textures. Comparison of the measurement results according to the present invention, on the one

hand, with reference samples whose period was determined according to the elaborate test-score method, on the other hand, has shown that the correspondence is very good and e.g. in the period range of from 70 to 110 μm a maximum error of $\pm 5 \mu\text{m}$ is to be expected.

The spacing of the intensity maxima can immediately be determined, at least to rough approximation, on the matt panel 10. For example, the matt panel may be provided with a graduated scale and the spacing of the intensity maxima can be read off using it. If the graduated scale on the matt panel is movable, its zero point can be made to coincide with one of the intensity maxima, for example the brightest one, and then the spacing of the intensity maxima can be read off from the graduated scale. It might also be possible to gauge the spacing of the intensity maxima using a pair of dividers and to transfer this reading onto a ruler, or to gauge it directly using the legs of callipers. However, these simple methods are only recommendable with reservation, or as a preliminary method.

The handset 1 with visual evaluation of the secondary light is used for manual and retrospective inspection of finished workpieces, for example so that twisted workpieces can be rejected and sent back for reprocessing. This may be done by an inspector or by the supervisor of a production line on which torsion-free journal surfaces are intended to be produced. In general, visual and qualitative identification of the wave pattern itself, or a clear indication of its absence, is sufficient for the selection of torsion-free workpieces, whereas in this case it is less important to quantify the parameters of any wave pattern which is found.

As already mentioned above, the handsets may be equipped with "intelligent" photodetectors, which can also perform certain measurement and computation operations automatically. Handsets equipped in this way

may output on a display at least the period L - and in the case of increased, integrated computation or evaluation power - also the depth T of any detected wave pattern. Although, without compromising their easy
5 handleability, such handsets may also be equipped so that they can store identified parameter values if desired, such handsets are not generally conceived for storing large amounts of data.

It is also conceivable to use the wave-pattern
10 measuring instrument according to the invention for automatic long-term monitoring of machine lines on which torsion-free journal surfaces are intended to be produced. In particular, those wave-pattern measuring instruments intended for constant use need to be equipped
15 with an evaluation unit which measures and calculates the secondary light. Any production or error data which may be determined using a wave-pattern measuring instrument integrated in the manufacturing process should be collected, stored and evaluated in chronological order by
20 a production-data logger or memory, in connection with other machine-operation data, inter alia such as e.g. the workpiece rotation speed, the grinding-head rotation speed, the grinding-head advance, the dressing advance, the workpiece number after the last dressing process in
25 the case of circumferential grinding. From the large amount of data and the fact that wave patterns have or have not occurred, production experience can then be gained empirically and critical parameter pairings can be avoided. This online production monitoring using a
30 powerful and continuous data memory may be integrated in the machine or may take place away from the immediate production line in a quieter room for production monitoring.

During the wave-pattern detection, the intensity
35 distribution of the secondary light 8 over its cross-sectional area may be converted into a data-processable

record of the image data, for example such as the one represented in negative at the upper part (a) of the image in Figure 7. This image-data record may be evaluated with respect to the occurrence of intensity maxima I_1 , I_2 in a correspondingly pre-programmed computer or in an "intelligent" photodetector integrated in the instrument, these being labelled as structural phenomena of the secondary light by the capital letters I_1 , I_2 . Conversely, the intensity values in these maxima are referenced by lower-case letters i_1 , i_2 . Since not all the diffraction orders are represented as clearly as in Figure 7, with two clearly recognisable intensity maxima, namely a main maximum I_1 of the zeroth diffraction order and a subsidiary maximum I_2 of the first diffraction order, but instead often have relatively strong specular noise superimposed on them, it is expedient firstly to subject the image data of the intensity distribution of the secondary light to an autocorrelation. In particular, less strongly pronounced torsional structures have stochastic roughnesses of approximately equal magnitude superimposed on them, so that an autocorrelation is particularly important in this case. The autocorrelation function represents a smoothing of the intensity profile in the diffraction orders, so that the maxima are readily detectable. From the values of the autocorrelation function, e.g. at the positions of the zeroth and of the first diffraction orders, it is possible to determine the intensity values i_1 and i_2 in these diffraction orders. Figure 7 shows the profile of such an autocorrelation function along a line b-b (see Figure 7, part a) within the two-dimensional intensity distribution in the diffraction image. The spacing a of the two maxima I_1 and I_2 , and the respective function value i_1 and i_2 of the autocorrelation function in the intensity maxima themselves, can be determined by computation - as mentioned.

As already mentioned above, the period L of the wave pattern can be calculated approximately according to a simple reciprocal relationship from the distance a which has been determined. However, the diffraction image
5 also supplies depth-relevant information about the diffracting wave-pattern structure on the workpiece surface, this being due to the fact that not only the wave crests but also the wave troughs contribute to the creation of the diffraction image. For example, different
10 diffraction images are obtained from two waved surfaces which have the same wave-pattern period as each other but a different wave-pattern depth from each other. The depth T of the wave troughs between the wave crests 27 can be deduced from the two intensity values i_1 and i_2 of the
15 main and subsidiary intensity I_1 and I_2 while taking the period into account. This calculation method is not quite as simple as the calculation of the period. In order to be able to determine the depth T of the wave troughs, it is first necessary to calculate a normalising auxiliary
20 variable k from the intensity values i_1 , i_2 by using the equation $k = i_1 \times i_2 / (i_1^2 + i_2^2)$. This relationship - incidentally like the approximate reciprocal relationship mentioned above for the period L of the wave pattern - is valid if certain idealising simplifications are applied,
25 although these are readily available with the instrument design recommended in the present case. The auxiliary variable k tends towards zero for extremely low intensities. The brighter the first diffraction order is, and hence the closer its intensity is to the intensity of
30 the zeroth diffraction order, the closer the auxiliary variable k will be to the "saturation" value of 0.5. Most practical cases will lie between the extremes just mentioned, that is to say in the maximum-spread range of the diagram lines in Figure 8. By using this auxiliary
35 variable and the period L which was already determined previously, the depth T of the wave troughs can be

determined with the aid of the graph according to Figure 8, which may also be stored as a data record in a computer and may be incorporated in the calculation.

Comparison of the results obtained in this way
5 for the wave depth T with the values found using the
test-score method shows a very good correlation. The
depths determined according to the invention are,
however, consistently somewhat lower than the reference
values in the case of ground surfaces, specifically at
10 about 62 ± 5 % of the reference values according to the
test-score method. This difference is attributable to the
different bandwidth limitations of the two methods.
Although the test-score method also picks up details of
the grinding topography, these details are suppressed in
15 the case of grazing illumination. In the event that
direct comparison is required, the depth values found
according to the invention need to be multiplied by a
correction factor (about 1.6 in the case of ground
surfaces).

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Patent Claims

1. Method for detecting small periodic wave patterns
5 in technical surfaces, in which the surface is
illuminated using a beam of monochromatic coherent light
- primary light - and a diffraction image of the periodic
wave patterns is produced in the secondary light returned
by the surface, the primary light being directed onto the
10 workpiece surface at a large angle of incidence with
respect to the surface normal to the surface of the
workpiece and approximately at right angles to the
expected periodic wave patterns, and the intensity
distribution of the diffraction image being evaluated,
15 characterised in that
for isolated determination of the wave pattern (26) of
ground surfaces, in which the wave pattern (26) has
finer, steeply indented stochastic ground structures (24)
superimposed on it, the ground structures (24) are
20 shadowed (shadows 25) by approximately grazing incidence
of the primary light onto the workpiece surface at a
constant angle of incidence within the angular range of
about $83 \pm 2^\circ$, and in that because of an isolated
illumination of the wave patterns (26) thereby achieved
25 with primary light on their side edges facing towards and
away from the light and on their wave crests (27), a
diffraction image solely representing the wave patterns
(26) is produced.
2. Method according to Claim 1, characterised in
30 that the secondary light (8) is collected on a matt panel
(10) and its intensity distribution is evaluated visually

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with respect to the occurrence of intensity maxima (I_1 , I_2).

3. Method according to Claim 1, characterised in that the intensity distribution of the secondary light (8) is measured as a function of position over the image
5 area of the diffraction image, and the measurements are evaluated with respect to the occurrence of intensity maxima (I_1 , I_2).

4. Method according to Claim 3, characterised in that the intensity distribution of the secondary light
10 (8) is subjected to an autocorrelation, and the autocorrelation function obtained therefrom is evaluated.

5. Method according to one of Claims 1 to 4, characterised in that the (a) spacing of neighbouring intensity maxima (I_1 , I_2) is determined, and the period
15 (L) of the wave pattern (26) is deduced therefrom.

6. Method according to one of Claims 1 to 4, characterised in that the intensity values (i_1 , i_2) of neighbouring intensity maxima (I_1 , I_2) are determined, and the depth (T) of the wave troughs between the wave crests
20 (27) is deduced therefrom and from the period (L) of the wave pattern (26).

7. Arrangement for detecting small periodic wave patterns in the surface of a workpiece, comprising a meter, which can be placed in a defined way on the
25 workpiece surface to be analysed, with a primary-light source which directs a primary light of monochromatic, coherent light beam onto the workpiece surface in a specific direction and a secondary-light display which collects the scattered-light cone returned by the
30 workpiece surface in the meter, in particular for carrying out the method according to one of Claims 1 to

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6, characterised by all the following features of the meter:

- at least in the region where the primary-light beam (7) emerges from the meter (1), this beam is directed (16) in such a way that, when the meter (1) is placed properly on the workpiece (11), it strikes the workpiece surface (12) to be analysed at a specific angle in the range of $83 \pm 2^\circ$,
- the meter (1) is designed in such a way that, after placing on the workpiece surface (12), it can be aligned with respect to the primary beam (7) at least approximately at right angles to any expected periodic wave patterns (26) of the workpiece surface (12),
- the secondary-light display collects the scattered-light cone directly, i.e. without imaging optics, as a diffraction image of the wave pattern (26), and the intensity distribution in the diffraction image can be evaluated.

8. Arrangement according to Claim 7, characterised in that, in the area (2) where it is applied to the workpiece surface (12), the device (1) encloses an exit window in whose lateral boundary optical deviating elements such as mirrors (14, 15) or deviating prisms for the primary beam (7) and the secondary beam (8) are arranged, which bend them in a space-saving way such that the beam component of the primary beam located in front of the primary-beam deviating element (14) and the beam component of the secondary beam located behind the secondary-beam deviating element (15) are aligned approximately at right angles to the workpiece surface (12).

9. Arrangement according to Claim 8, characterised in that the optical deviating elements (14, 15) are

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arranged in such a way that the beam component of the primary beam (7) located in front of the primary-beam deviating element (14), on the one hand, and the beam component of the secondary beam (8) located behind the secondary-beam deviating element (15), on the other hand, cross each other.

10. Arrangement according to Claim 7, characterised in that the secondary-light display is designed as a matt panel (10) which makes the intensity distribution of the diffraction image visually perceptible.

11. Arrangement according to Claim 7, characterised in that the secondary-light display is designed as a linear or two-dimensional matrix of a plurality of photoreceptive sensors which measures the intensity distribution of the diffraction image.

12. Arrangement according to Claim 7, characterised in that both a matt panel (10), which makes the intensity distribution of the diffraction image visually perceptible, and a linear or two-dimensional matrix of a plurality of photoreceptive sensors, which measures the intensity distribution of the diffraction image, are arranged in the secondary-light display, and the secondary-beam path is accessible to them via a beam splitter or via a tilting mirror.

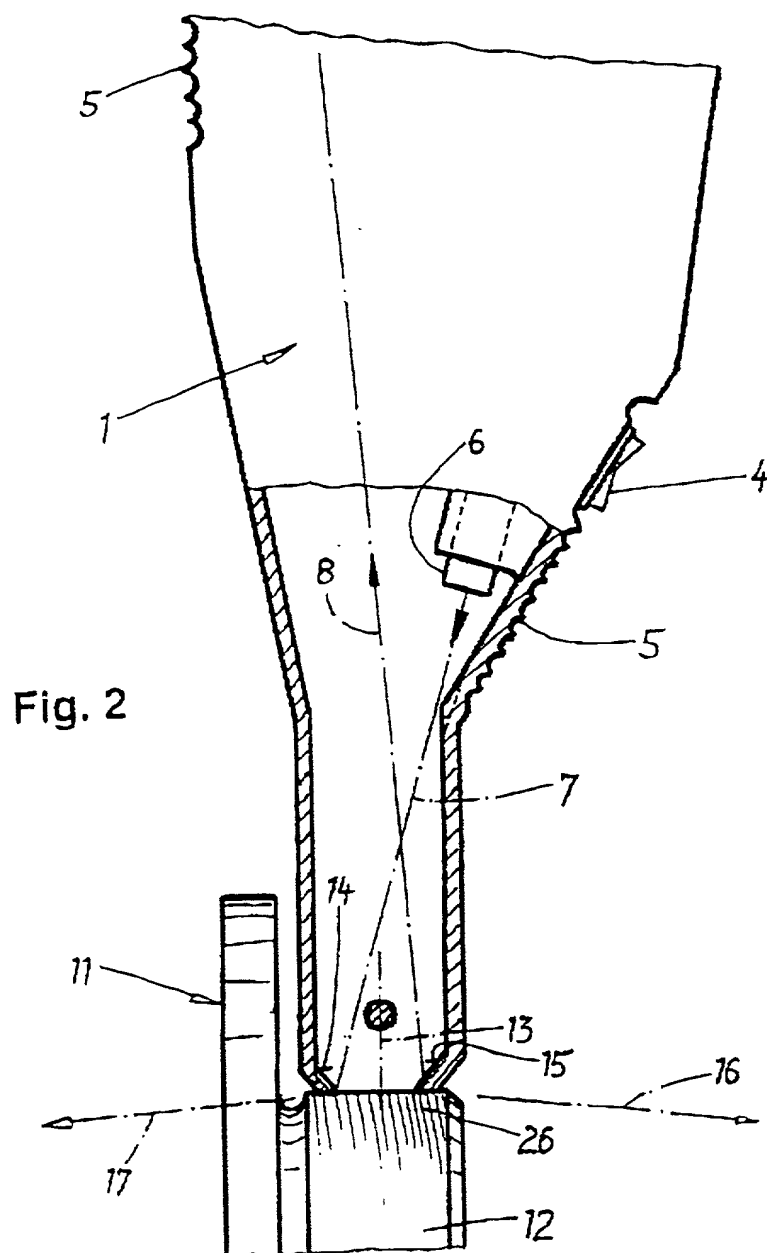
13. Arrangement according to Claim 12, characterised in that a digitally operating camera (23), which can be used to record the intensity distribution of the diffraction image of the secondary-beam path (8), is fitted (22) to the meter (1).

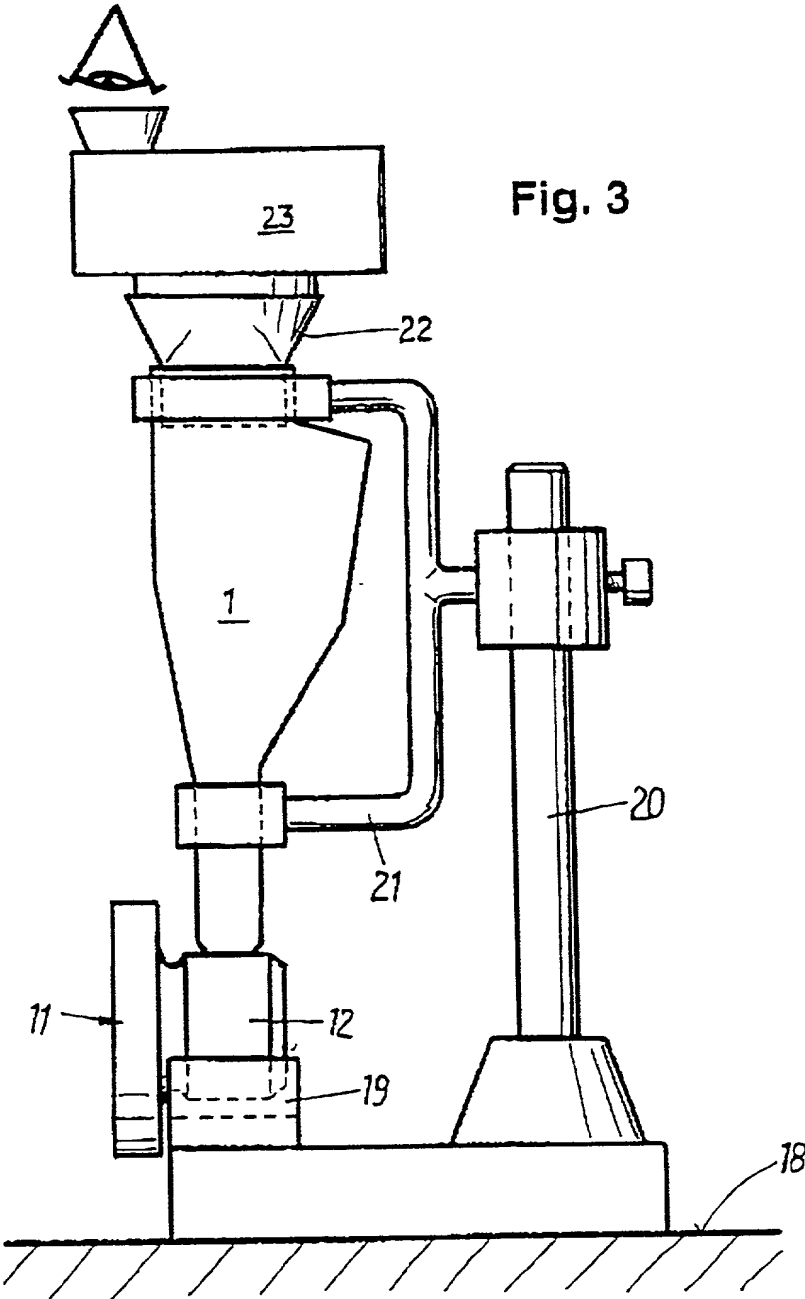
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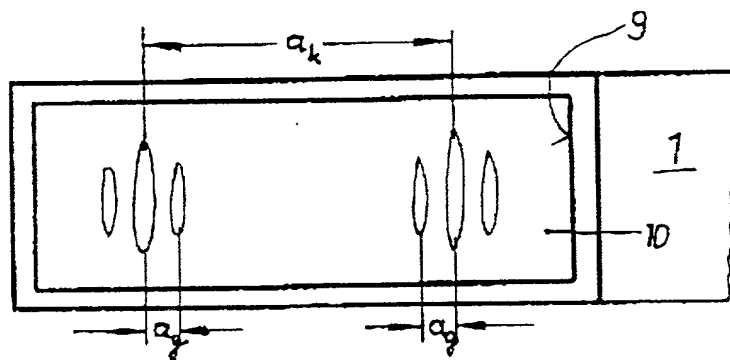
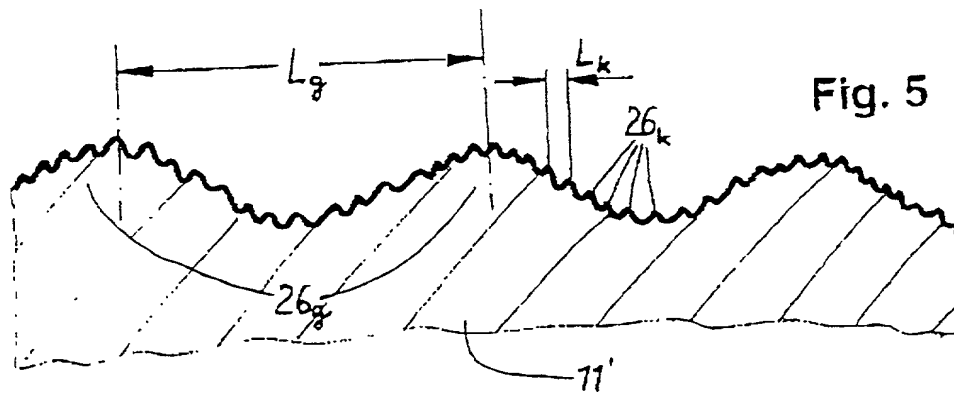
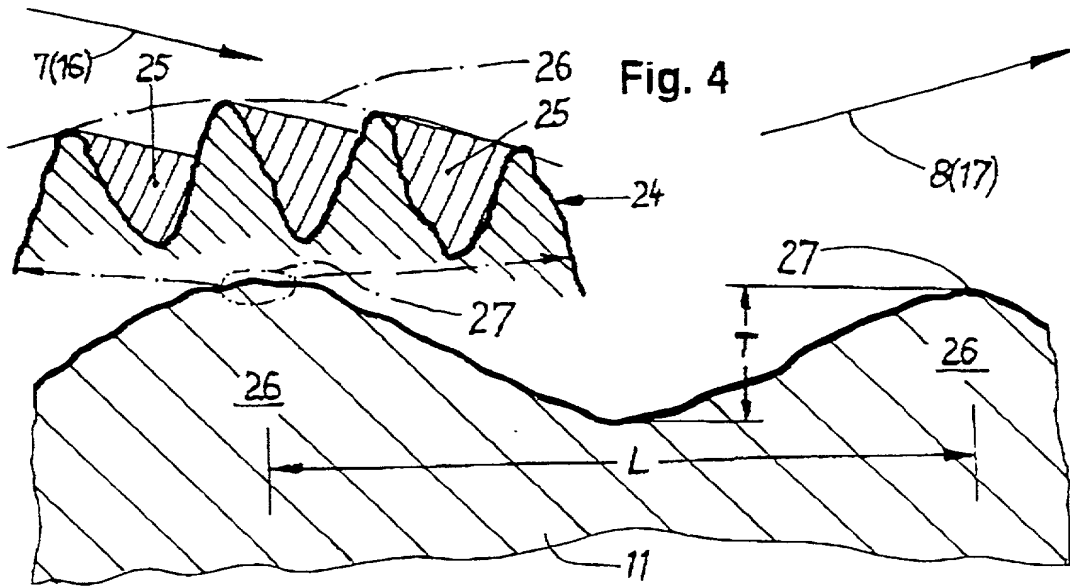
Abstract

The invention relates to a method and to an arrangement for detecting small periodic wave patterns in technical surfaces using the scattered-light method, in which the surface is illuminated using a light beam - primary light - and the secondary light returned by the surface is analysed. In order to make it possible to take measurements quickly, conveniently and with reproducible information being obtained in this way, even under robust factory working conditions, the invention uses monochromatic, coherent primary light which is directed onto the workpiece surface approximately at right angles to the expected periodic wave patterns - grazing the workpiece surface. A diffraction image of the waved surface structure, whose intensity distribution can be evaluated visually or by use of measuring instruments, is produced in the secondary-light pencil by means of this. The occurrence of two intensity maxima immediately indicates the presence of a periodic wave pattern. The period of the wave pattern can be deduced through inverse proportionality from the spacing of neighbouring intensity maxima, and the depth of the wave troughs between the wave crests can be deduced from the intensity of neighbouring intensity maxima and from the period. The intensity distribution in the diffraction image in the secondary-beam path is subjected to an autocorrelation, and both the period and the depth of the wave pattern can be calculated from the autocorrelation function. When the meter is placed properly on the workpiece, the primary-light beam strikes the workpiece surface at an angle of incidence of preferably about 83 ± 2 degrees, the beam path being folded in a space-saving way.

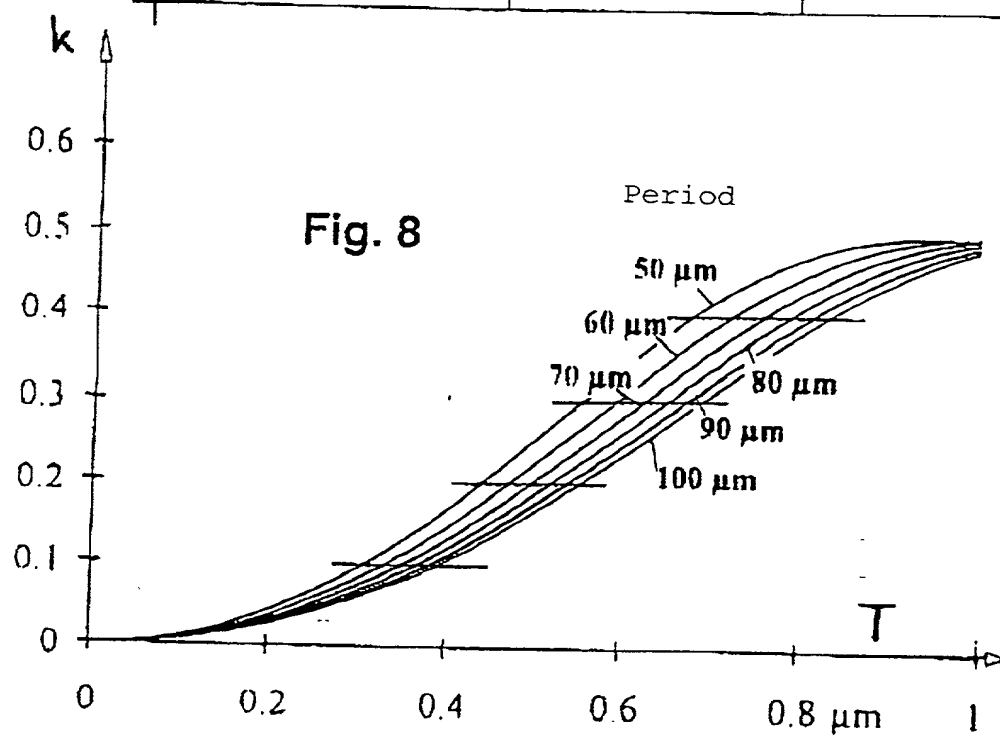
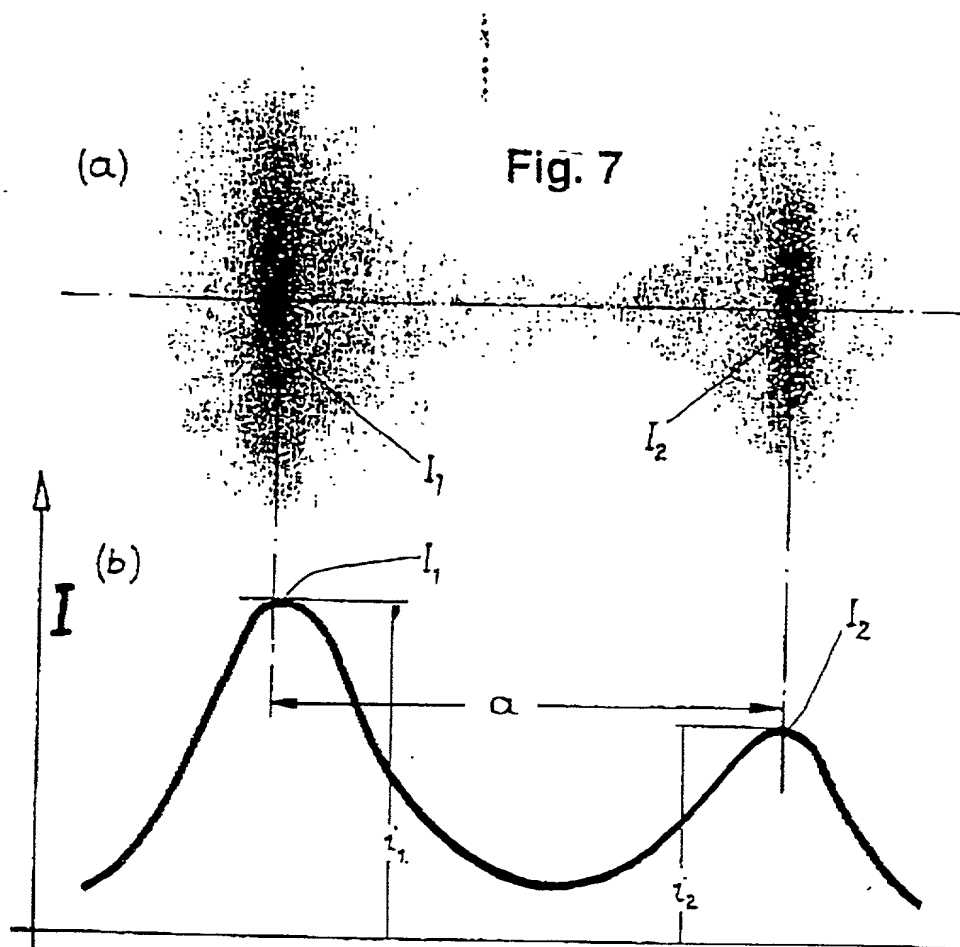








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COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY
(includes Reference to PCT International Applications)

ATTORNEY'S DOCKET NUMBER
225/49845

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD AND DEVICE FOR DETECTING AND MEASURING SMALL PERIODIC WAVE PATTERNS IN TECHNICAL SURFACE

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application

Serial No. _____

on _____

and was amended _____

on _____ (if applicable).

☒ was filed as PCT international application

Number PCT/EP99/06591

on 07 September 1999 (07.09.99)

and was amended under PCT Article 19 _____

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I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations. §1.56(a).

I hereby claim foreign priority benefits under Title 35, United State Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

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COUNTRY (if PCT indicate PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Germany	198 46 302.2	8 October 1998 (08.10.98)	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No



23911

PATENT TRADEMARK OFFICE

Combined Declaration For Patent Application and Power of Attorney (Continued)
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UNDER 35 U.S.C. 120

U.S. APPLICATIONS			STATUS (Check one)		
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